VII. *On the Dip of the magnetic needle in London, in August* 1828. *By Captain* EDWARD SABINE *of the Royal Artillery, Secretary of the Royal Society.*

Read January 8, 1829.

THE Philosophical Transactions contain the record of the dip of the magnetic needle in London, observed at irregular intervals since the early part of the last century. In comparing these, and particularly the results obtained by Messrs. WHISTON and GRAHAM in 1720 and 1723, with those of Messrs. NAIRNE and CAVENDISH in 1772 and 1775, and both with the dip as it exists at present, we have satisfactory evidence of the progressive diminution of the dip in London during the whole of the period in question; but the observations are too few in number and infrequent, and the earliest ones particularly too doubtful in point of accuracy, to enable us to determine whether the annual diminution has been uniform or otherwise.

In the Philosophical Transactions for 1822, Art. I. the Society did me the honour to publish an account of observations which I had made in the Regent's Park, in August 1821, to obtain a correct determination of the dip in London at that time; in which observations I employed, for the first time in this country, a needle constructed on a plan proposed by Professor MEYER of Göttingen, for avoiding the usual error of dipping needles arising from the non-coincidence of the centres of motion and gravity. Seven years having since elapsed, an interval perhaps not too small to throw light upon the present rate of diminution of the dip, I repeated the observations in the August of last year, an account of which I now present to the Society; changing the place of observation, in consequence of the increase of buildings in the Regent's Park, to the Garden of the Horticultural Society at Chiswick, distant about six miles, in a direction coinciding as nearly as possible with the line of equal dip passing through the Regent's Park.

The general apparatus employed is the same that I used in the observations

of 1821: the limb is a circle of twelve inches diameter, each quadrant being graduated from 0° at the horizon to 90° at the vertical, and divided into spaces of 20′. The vertical edges of the agate supports, on which the axis of the needle rests, are rendered horizontal by a circular brass plate carrying a spirit-level; the lower surface of the plate is carefully ground, and being placed on the supports and turned successively in the four principal directions, the adjustment is made by the foot-screws of the instrument until the bubble of the level is stationary in every direction in which the plate is turned. The divisions 90°, and 90° of the circle marking its vertical points, ought then to coincide (and should they not do so, there is an adjustment to render them coindent,) with the points of conical radii, proceeding from the surfaces of the plate at right angles to it. By means of this plate, the level, by which the horizontal adjustment is effected, is applied directly to the supports, and the graduation of the circle made also to correspond with them.

The needle which was first used, was a flat needle of the ordinary construction 11.5 inches long, .4 broad, and .05 thick, rounded at the extremities. Three distinct observations were taken with it in each of the following positions; and as the arc was read at both ends of the needle, six readings were obtained in each position.—1st, with the face of the instrument to the east, and the marked side of the needle also to the east; 2nd, with the face to the east, and the marked side of the needle to the west; 3rd, with the face of the instrument to the west, and the marked side of the needle to the west; 4th, with the face to the west, and the marked side of the needle to the east. The poles were then changed, and the same course of observation gone through as before. The poles were changed by bar magnets in the usual way; the magnets were passed along the flat surfaces of the needle, ten times on each side; the needle being laid in a groove, which confined the motion of the magnets to a direction parallel to the needle. The force of magnetism imparted to the needle, on each occasion when its poles were changed, was measured by the time of performing 10 vibrations always in similar arcs. The horizontality of the supports was examined afresh every time the instrument was turned in azimuth; and no pains were spared to obtain results which might be consistent with each other, as I intended afterwards to apply the small screw and weight devised by Professor Meyer to the same needle, and wished to compare its perform-

ance as an ordinary needle, with its performance when used in the manner recommended by the Professor.

For the purpose of distinction, one of the ends of the needle had a mark upon it which the other end had not. In consequence of the axis of the needle not being perfectly coincident with the centre of gravity, the dip shown by it was too great when the marked end was a North Pole; and on the other hand, when the unmarked end was a North Pole, the dip shown was too small. After the two first experiments with the needle, this discrepancy was in great measure removed, by taking off a very small quantity from the marked end of the needle by means of a grind-stone. The following are the results obtained with this needle used in the manner described:

August 11th & 12th. From Noon to 4 P.M. Therm. 66°.

		Time of Vib^{n}.			
Exp. I.	Marked end a S. Pole	53^{s}.6	24 Readings	66° 23′.3	Mean 69° 26′.8
	Marked end a N. Pole	48 .4	24 Readings	72 30 .3	
Exp. II.	Marked end a S. Pole	52 .8	24 Readings	66 23 .1	Mean 69 37 .5
	Marked end a N. Pole	49 .6	24 Readings	72 51 .9	
Exp. III.	Marked end a S. Pole	46 .8	24 Readings	70 38 .8	Mean 70 14 .0
	Marked end a N. Pole	52 .8	24 Readings	69 49 .2	
					Mean . . . 69 46 .1

The same needle was then fitted with a small screw, inserted vertically in a line with the axis, and perpendicular to the needle; and brass beads of different sizes were successively used in the following experiments, in the manner and for the purposes recommended by Professor Meyer. Three distinct observations were made with the weight undermost when the face of the instrument was towards the east, and the same number with the face towards the west, both ends of the needle being read off on all occasions: the same process was then gone through with the weight uppermost; and finally the poles were changed, and the whole proceeding repeated. The dip is then deduced from the observations by the formula given for that purpose by Professor Meyer.

August 13th & 15th. Noon to 3 P.M. Therm. 67°.

		Time of Vib^{n}.			
Exp. IV.	Marked end a S. Pole	53^{s}.6	W. below;	61° 55′.5	Dip 69° 48′.3
			W. above;	80 30 .7	
	Marked end a N. Pole	54 .0	W. below;	58 38 .6	
			W. above;	80 25 .7	

August 16th. 3 to 5 P.M. Therm. 66°.

		Time of Vib^{n}.			
Exp. V.	Marked end a N. Pole	54^{s}.0	W. below;	53° 07′.0	Dip 69° 42′.0
			W. above;	87 11 .2	
	Marked end a S. Pole	53 .6	W. below;	58 55 .2	
			W. above;	84 37 .6	

August 20th. Noon to 2 P.M. Therm. 68°.

Exp. VI.	Marked end a S. Pole	53^{s}.6	W. below;	57° 28′.7	Dip 69 58 .8
			W. above;	87 33 .4	
	Marked end a N. Pole	52 .8	W. below;	52 48 .3	
			W. above;	88 19 .8	

August 20th. 4 to 5 P.M. Therm. 67°.

Exp. VII.	Marked end a N. Pole	W. below;	52° 06′.0	Dip 69 40 .5
		W. above;	89 51 .0	
	Marked end a S. Pole	W. below;	57 12 .0	
		W. above;	86 13 .0	
			Mean . . .	69 47 .4

With the same general apparatus I employed also two other needles: one a flat needle with a cross of wires attached to the axis, two in the longitudinal direction of the needle, and two at right angles to it. By means of small weights sliding on these wires, the axis could be brought very nearly, if not exactly, to coincide with the centre of gravity. The same number of observations were made with this needle, and in the same general manner as in the experiments numbered I, II, and III. The following is the result obtained.

August 20th. 2 to 4 P.M. Therm. 69°.

Exp. VIII.	Marked end a N. Pole	24 Readings	69°34′.25	Dip 69°38′.3
	Marked end a S. Pole	24 Readings	69 42 .35	

The other needle was on a plan proposed some time ago by Mr. Dollond. The two ends of this needle are conical; the bases of the cones occupy two sides of a cube, which forms the middle of the needle; the other four sides being perforated for the purpose of receiving the axis in every direction. These sides are numbered for distinction 0, 1, 2, 3; 0 being opposite to 2, and 1 to 3. The axis is passed through the perforation until a shoulder on the one arm of the axis blocks against one of the sides of the cube, 0 for example: a nut is then screwed on the other arm of the axis against the side 2, until the axis is tightened in its place, care being taken that the same parts of the axis coincide

always with the longitudinal plane of the needle. The dip is then observed and registered with the face of the instrument successively towards the east and towards the west. The axis is then changed end for end, the nut that was before screwed against the side 2 being now screwed against the side 0; and the dip again observed with the face of the instrument east and west. The axis is then passed through the needle in a direction perpendicular to what it was before, the nut being screwed, for example, against the side 1, and the dip observed; the axis is then changed end for end, and the dip again observed. There are thus sixteen distinct observations in different positions of the axis and instrument: this number is doubled by reversing the poles and repeating the whole operation; and as both ends of the needle are required to be read, there are sixty-four arcs observed for each determination of the dip. In the present case two distinct observations were made in every position of the needle, axis, and instrument, and the dip is therefore an arithmetical mean of 128 observed arcs. In the following abstract the reference to the sides implies that the nut on the arm of the axis was screwed against that particular side of the cube in the observations referred to it.

August 13th & 15th. 3 to 5 P.M. Therm. 66°.

Exp. IX.	Marked end a N. Pole	Side 0; 70° 52′.0	70° 54′.9	;	Side 1; 70° 33′.8	70° 55′.3	
		Side 2; 70 57 .7			Side 3; 71 16 .8		
	Marked end a S. Pole	Side 0; 69 44 .5	68 48 .5	;	Side 1; 67 44 .0	68 48 .0	
		Side 2; 67 52 .6			Side 3; 69 52 .0		
			69 .51 .7			69 51 .65	
			Mean . . 69° 51′.67				

Captain Franklin having kindly obtained from the Colonial Department the use of a small apparatus for determining the dip which he carried with him in his last land expedition, I am enabled to add the result of four series of observations made with it in the Garden at Chiswick, at the same time as the preceding observations, by Mr. David Douglas of the Horticultural Society. The circle is of six inches diameter only, being made so small for greater portability: except in size, the whole apparatus is in all respects similar to the one with which the observations already detailed were made. The agate supports are levelled in the same manner by a circular plate carrying a

level, and the mode of observation was the same in every particular. The needle was fitted with a screw and weights, on Professor MEYER's plan.

Exp. X. Aug. 18.	Marked end a N. Pole.	W. below;	52° 05′.5	Dip 69° 01′
		W. above;	89 38 .0	
	Marked end a S. Pole.	W. below;	56 11 .9	
		W. above;	85 12 .3	
Exp. XI. Aug. 19.	Marked end a S. Pole.	W. below;	62 24 .0	Dip 69 42
		W. above;	77 54 .0	
	Marked end a N. Pole.	W. below;	62 19 .0	
		W. above;	77 42 .5	
Exp. XII. Aug. 19.	Marked end a N. Pole.	W. below;	63 57 .5	Dip 70 38
		W. above;	77 46 .0	
	Marked end a S. Pole.	W. below;	63 42 .0	
		W. above;	78 22 .5	
Exp. XIII. Aug. 20.	Marked end a S. Pole.	W. below;	55 39 .0	Dip 70 04 .5
		W. above;	87 30 .0	
	Marked end a N. Pole.	W. below;	53 32 .0	
		W. above;	90 58 .0	
			Mean . . .	69 51 .4

The several results which have been enumerated, being collected in one view, are as follows:

Instrument of 12 inches diameter. Observer, Captain SABINE.

Exp. I, II, & III, with a common needle	69° 46′.1
Exp. IV, V, VI, & VII, with MEYER's needle	69 47 .4
Exp. VIII, with a needle having an adjustable axis . .	69 38 .3
Exp. IX, with Mr. DOLLOND's needle	69 51 .7

Instrument of 6 inches diameter. Observer, Mr. DOUGLAS.

Exp. X, XI, XII, & XIII, with MEYER's needle	69° 51′.4
Mean . . .	69 47 .0

Whence the final result of the dip in the Horticultural Garden at Chiswick, in August 1828, is 69° 47′ North.

The result of the observations in August 1821 was 70° 04′.5 (Phil. Trans. 1822: Art. I.); whence the dip in London appears to have diminished 17′.5 in

seven years, or 2′.5 in each year. This rate of diminution is sensibly less than the general average resulting from the comparison of the most authentic observations, at considerable intervals apart, in the century preceding 1821. These results fall variously between the limits of 2′.9 and 3′.2. Did the observations of 1821 and 1828 stand alone, in indicating a decrease at the present time of the amount of the annual change in the dip in this part of the world, it would appear the more probable supposition that either of those observations might be in error the few minutes which would be sufficient to make their difference correspond with former observations; and still more probable that they might contain between them an error of that small amount. But if we examine the very correct and consistent series of observations on the dip at Paris, commenced by M. Humboldt in 1798, and continued in subsequent years by MM. Gay Lussac, Humboldt, and Arago, we find in them a similar indication of diminution latterly in the annual decrease of the dip. If, for example, we divide the interval of thirty years between 1798 and 1828, into two nearly equal portions by means of the observations made by M. Arago in 1812, we have for the first portion, containing fourteen years, a diminution of ($69° 51′ - 68° 42′ = 69 \div 14 =$) 4′.93 a year; and for the second portion, containing sixteen years, of ($68° 42′ - 67° 58′ = 44 \div 16 =$) 2′.75 a year. And if instead of dividing the interval by M. Arago's observations in 1812, we take for that purpose the conjoint observations of MM. Humboldt and Arago in 1810, we have for the first portion, containing twelve years, ($69° 51′ - 68° 50′ = 61 \div 12 =$) 5′.08 a year; and for the last portion, containing eighteen years ($68° 50′ - 67° 58′ = 52′ \div 18 =$) 2′.89 a year: all which indications are of the same character and accord well with the observations of 1821 and 1828 in London.

A repetition of the observations in London at the expiration of another seven years, and a continuation of those at Paris, will probably show decisively whether the annual change in the amount of the dip in this part of the world is diminishing, as there now appears reason to suspect. Should it prove the case, careful and frequent observations of the dip will possess a more than ordinary interest, since the correct determination of the precise period when the dip may become stationary, and its amount at that time, which would be its minimum limit, will form most important additions to our knowledge of the phænomena of terrestrial magnetism.